

## **Bottom Stationed Ocean Profiler**

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### **LONG-TERM GOAL**

The long term goal is development and utilization of a bottom stationed autonomous ocean profiler. The system is capable of bi-directional satellite communication via the ORBCOMM system, is user programmable and can store and/or transmit acquired data in near real-time. Deployment of large numbers of BSOP systems, each equipped with a highly capable sensor suite, can be used to synoptically observe marine environments with very low initial capital investment and even lower operations costs.

### **OBJECTIVES**

The project's objective is to develop a bottom stationed ocean profiler (BSOP) capable of up to 150 profiles over a 3 month time period. BSOP will have a satellite link and near real-time communication capability. The initial BSOP array will consist of four modular units with variable sensor payloads and ten unitary CTD-equipped profilers. Testing of developed units will take place in near shore and local waters.

### **APPROACH**

Our Bottom Stationed Ocean Profiler (BSOP) is a drifting sensor package designed for use in the littoral environment. It follows from previous drifting system developments (Davis, et al. 1992); the significant difference being an ability to hold general position by stationing on the sea floor. Two specific designs are being pursued: (a) an existing modular design and (b) an under-development unitary version. Both of these can be described in terms of the following components: 1) Control System; 2) Transmission System; 3) Buoyancy System; 4) Payload Sensors; 5) Power Supply; and 6) Emergency

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Abort and Safety Features. Outfitted with a CTD, BSOP is designed to provide relatively inexpensive, synoptically sampled, near real-time profiles for mapping large-scale material property fields and assimilation of these data into models. Other applications with advanced chemical, biological, physical, and optical sensors are in development for broad-based adaptive sampling in support of Navy defense-related and civil applications.

BSOP is designed to ascend at approximately 0.5 meters per second or less. CTD and payload data are acquired at 2 m intervals and stored in internal memory. Once on the surface, the unit transmits acquired data and GPS location fixes via a satellite communication link. Each transmission consists of data gathered from the previous descent-ascent cycle. Upon completion of data transmission, each unit floods its internal buoyancy canister and descends at up to 0.5 meters per second, gathering data until impact with the sea floor. The internal microprocessor then shuts down power and enters a "sleep" mode until an internal real time clock initiates wakeup and the cycle repeats.

The remote communications transceiver utilizes the ORBCOMM system. All data are, as well, stored within flash memory for retrieval upon recovery of the profiler. The transceiver also acts as a backup microcontroller capable of triggering an abort sequence for recovery of the unit.

Deployments incorporate a program with a user-defined duration up to 100 cycles. Presently work is continuing on both the original modular unit as well as a unitary design.

## **WORK COMPLETED**

### **Modular Profiler**

The instrument frame is constructed of aluminum and is modular. The modules are mechanically connected as contiguous tubes to minimize hydrodynamic drag. This allows units to ascend and descend at designed rates with minimal drift during each cycle. The modules are configured to ensure that each profiler's center of gravity is far below its center of buoyancy. This, along with the tubular, low drag construction, allows the unit to maintain a generally fixed attitude at the surface and while ascending or descending.

### **Control Module**

The control module consists of the micro controller, remote communications transceiver, internal communications network controller, backup power source, and supporting electronics. The entire unit is controlled by the OSIS micro controller system developed at the USF Center for Ocean Technology. The OSIS system is based on the Motorola 68HC16, has up to 80 megabytes of internal data storage memory, a real-time clock, and a very low power sleep-mode capability. A lithium coin cell powers the micro controller's real-time clock and watchdog timer.

The communication system is a bi-directional satellite link using the ORBCOMM system. The Quake 1500 (<http://www.quakewireless.com/>) transceiver system provides a 24-hour, nearly global daily coverage and allows rapid economical communication while the profiler is on the surface. The transceiver allows outgoing transmissions of data and profiler status, provides GPS fixes, and accepts user-defined mission changes on each cycle. Emails sent (via internet) from a shore-based operator to a remote profiler can be used to alter the profiler's operating characteristics (e.g. cycle frequency, profiling velocity, sample rates, etc.). The transceiver also acts as a backup controller by monitoring a

status line connected to the main micro controller. Failure of the micro controller will trigger a transceiver mission-abort-mode transmission.

Communication between modules is established using the LONWorks system designed by Echelon (<http://www.echelon.com>). This system allows inter-communication of all components within the system by utilizing two conductors connected to each module through the main wiring buss. Each module is a network node that serves a specific function under the direction of the main microcontroller.

### **Antennas/Radio Beacon**

The profiler is equipped with an ORBCOMM antenna, GPS antenna, and a radio beacon/xenon flasher, all located above water when the unit surfaces. The ORBCOMM and GPS antennas are commercially available antennas modified to withstand the 200m design-depth of the profiler, and are rewired with custom COT designed underwater coaxial connectors. The radio beacon/xenon flasher is a Novatech RF-700C5 (<http://www.novatechdesigns.com/RF-700C5.htm>)

### **Buoyancy Module**

The buoyancy canister consists of a pump (for oil evacuation) and motor-actuated valve (for flooding). The pump and valve are controlled via LON Works by the micro controller system. The oil reservoir (approximately one gallon) is able to provide approximately 7.5 lbs of adjustable buoyancy for the BSOP unit. For ascent, a gear pump is used to transfer oil from a reservoir in the pressure housing to a nitrile bladder within a flooded cylinder. An in-line check valve assures no backflow once the pump stops.

### **Sensor Payload**

The sensor payload area is expandable to accommodate a wide variety of sensors. At present the payload consists of a Falmouth Scientific 2" Micro-CTD ([http://www.falmouth.com/products/micro\\_ctd2/MCTD2.htm](http://www.falmouth.com/products/micro_ctd2/MCTD2.htm)) and a SEAS instrument (<http://cot.marine.usf.edu/project.asp?projID=9>). Expansion of accompanying sensors is straightforward. Changes in buoyancy due to changes in payload are effected by addition or removal of flotation at the top of the unit.

### **Power Supply**

The power supply uses lead acid batteries configured in an isolated "multibank" arrangement, where each bank is used in sequence. The micro controller monitors the status of each bank via LONWorks. A LONWorks module dedicated to monitoring battery status switches to the next bank when the current bank becomes exhausted.

### **Drop Weight**

Emergency ascents are accomplished using a drop weight system. When any of a number of abort criteria are experienced, an energized electromagnetic coil cancels the permanent magnetic field of a magnet holding the 4.5 kg drop weight. The drop weight housing includes a backup 24V lithium ion battery for use in the event of a main power supply failure. An additional pressure sensor also backs up the CTD to avoid pressures in excess of the design limit. A corrodible link (100 day) between the drop weight and the magnetically coupled release plate serves as a final failsafe in the event that a unit becomes flooded.

## **System Aborts**

Detected problems trigger an abort mode. The abort sequence releases the drop weight, evacuates the oil reservoir, and transmits an abort message. Abort messages inform the operators of the time and cause of the abort and contain a GPS fix. These emails will repeat at a predetermined cycle until battery power is exhausted. Once the retrieval vessel and crew are within range of the profiler, an email sent to the profiler allows it to switch to a retrieval state. In this state the remote communications transceiver turns on the radio beacon/xenon flasher.

A number of events can trigger the micro controller to enter an abort mode: low battery power; lack of communication with one of the profiler component modules; failure to ascend/descend; CTD depth data indicates profiler is below design depth; message that the drop weight has been released.

The drop weight itself can trigger an abort mode when: over pressure from the drop weight's backup pressure sensor signals that the unit has drifted below its design depth; a periodic 'heartbeat' signal from the micro controller is not received; a defined time in the powered-up (ON) state is exceeded; the drop weight's backup power supply drifts below a working voltage.

The remote communications transmitter can trigger an abort mode upon: direct command from an email; lack of communication with the micro-controller.

## **Unitary CTD Profiler**

The second version of the BSOP unit is directed toward design consolidation and simplification. The objective is to utilize the existing design described above to create a non-modular profiling float equipped with a fixed sensor package. The focus of the redesign is size and cost reduction, convenience, simplicity, and minimization of re-engineering, all while maintaining the functionality and reliability of the instrument.

The sensor chosen for the redesign is an Applied Microsystems Micro CTD (<http://www.appliedmicrosystems.com/index.html>). This will be integrated into the top endcap of the pressure vessel along with the Novatech beacon and both antennas.

The electronics and mechanics will undergo minimal redesign. The only modular-system component that will not be incorporated in the unitary system is the actively controlled drop weight. A weight connected via a corrodible link will be incorporated as a passive recovery mechanism. Under abort conditions, the buoyancy bladder will fill, sending the profiler to the surface where it will begin transmission of profiler-abort status.

Ten redesigned units are under construction.

## **RESULTS**

The principal focus of the past year's work has been extensive experimentation, testing, and debugging of the modular units. Significant packaging constraints, proximity effects between components, antenna matching and grounding issues, test locations and scenarios, surface buoyancy characteristics, and bottom composition characteristics have been dealt with both individually and simultaneously. As of this date a total of at least 17 missions have been run within Bayboro Harbor and at alternative field locations, not including a large number of laboratory simulations.

As a result of this work, the modular units are approaching readiness for extended offshore deployments. Final testing of software and antenna transmission variables is commencing. This will accelerate the progress of unitary profiler testing and redesign since most of the issues confronted have been addressed in the new configuration. At present, transmission success rates are approaching 80%.

A brief description of the main problems encountered in the project, not including simple operator error or software bugs, is given below:

Considerable interference between various components, and from sources within and outside the profiler, necessitated a painstaking analysis of each component's impact on communications. The utilization of a single antenna for both transmission at 150 Mhz and reception at 137 Mhz necessitated a compromise on the design wavelength. This compromise led to significant noise being reflected back to the transmitter during transmission. Bursts of noise were enough to disrupt some of the surrounding electronics, primarily the microcontroller and the LONWorks internal communication system. In order to maintain both waterproofing and proper transmission, several custom modifications of the manufacturer's supplied antenna were devised and tested.

Ground plane issues have played a major role in trouble shooting efforts. The ground plane inconsistencies between lab tests and seawater deployments were sufficient to preclude laboratory tests in favor of evaluations in the field that were more difficult and time-consuming. The various configurations tested included elimination of the ground connection, and adjustments in the size and configuration of the ground connection to seawater. It was found that the reception signal strength stabilized when the ground plane connection had sufficient surface area, and that the distance between the antenna and the sea surface has a modest impact on the signal strength. Elimination of galvanic corrosion on the aluminum profiler pressure vessels requires a ground-plane to seawater connection independent of the profiler itself.

It was found that our testing location, within Bayboro Harbor, adjacent the College of Marine Science facilities, is less than ideal for reception at the desired frequency. Significant radio frequency traffic at and around the reception frequency has made testing more difficult and occasionally delayed the identification of problems. Testing at remote locations was utilized when necessary.

In addition, Bayboro Harbor has a high sedimentation rate and muddy bottom, and several tests were cut short due to the suction created when the profiler settled into the bottom. This phenomenon is not expected during normal offshore deployments on the WFS.

The profiler surface buoyancy characteristics presented transmission problems. To increase our success rate, the antenna has been raised to 0.3 – 0.4m above the mean waterline interface of the profiler.

A long test cable, used during some tests, created excessive noise and several mission aborts. This cable will not be used in normal operations of the profiler.

Design changes in response to the problems noted above substantially increased the frequency of successful data transmissions, reduced mission aborts, and produced a much more robust profiling system.

## **IMPACT/APPLICATIONS**

This project represents a directed effort to build and test inexpensive and efficient systems for characterization of a wide variety of marine environments. Data gathered have direct application to predictive physical, chemical and biological process models. The systems being developed and tested are targeted for deployment in open ocean environments. Experience gained in deploying and developing the BSOP units will have a significant impact on the design of appropriate tools for future automated monitoring of the ocean.

## **TRANSITIONS**

The data output of this project will be of use in physical and chemical process-modeling. Investigators involved in measurements of optical properties of seawater and biological - chemical - physical process-models will use the developed system and its stream of real-time data.

## **RELATED PROJECTS**

- 1) ENHANCED IN-SITU SPECTROSCOPIC ANALYSES OF TRACE SEAWATER SOLUTES
- 2) CONSTRUCTION OF IN-SITU UNDERWATER MASS SPECTROMETER
- 3) TESTING AND REFINEMENT OF LONG PATHLENGTH LIQUID CORE WAVEGUIDE SENSORS FOR AUTONOMOUS IN-SITU ANALYSIS OF THE UPPER OCEAN
- 4) SMART SENSOR PROGRESSION: APPLICATION SPECIFIC CHEMICAL INFORMATION MICROPROCESSOR (ASCI Mp)